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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

Since the establishment of the *Species at Risk Act* (SARA) in 2002, there has been growing interest in oil and gas development in Canadian waters by the Offshore Petroleum Industry and the number of Exploration Licenses issued and seismic surveys conducted in land parcels off Nova Scotia and Newfoundland has been increasing. The 2014 Call for Bids for land parcels off Nova Scotia included areas identified as critical habitat of cetacean species listed as endangered under the SARA. Underwater noise, particularly loud sounds, can negatively impact cetaceans through a number of mechanisms and is considered a potential threat to individuals and populations. Concerns have thus been raised about the potential impacts of oil and gas exploration and mapping activities on SARA-listed cetaceans, particularly noise produced by seismic airgun arrays during seismic surveys.

Since 2008, the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) has been used to guide minimum mitigation measures required for seismic operations in all non-ice covered marine waters in Canada (DFO 2008). However, it has been questioned if the generic requirements of the SOCP are adequate to avoid SARA-prohibited impacts on cetacean species at risk and their critical habitat. The SOCP itself states that additional or modified mitigation measures may be required for species for which there is concern (DFO 2008) and member companies of the Canadian Association of Petroleum Producers and their seismic contractors have often put into place additional mitigation measures identified during the Environmental Assessment process to further reduce the impacts of seismic survey activities on vulnerable species and sensitive marine areas. There is currently little guidance though on what additional mitigation measures should be considered to ensure that SARA-prohibited impacts on SARA-listed cetaceans are avoided.

The increased interest in oil and gas exploration and mapping activities in areas with geophysical potential that overlap areas frequented by SARA-listed cetaceans (including identified critical habitat), has led to a need to evaluate the ability of the SOCP to avoid SARA-prohibited impacts, and to determine if additional or modified mitigation measures are needed. DFO Science Sector was thus requested to:

- Identify sound exposure metrics and thresholds for seismic survey activities that could be used to avoid SARA-prohibited impacts on SARA-listed cetaceans.
- Provide advice on whether the application of the current mitigation measures outlined in the SOCP would avoid SARA-prohibited impacts on SARA-listed cetaceans.
- Identify potential modifications to the current SOCP or additional mitigation and monitoring measures that could be used to meet SARA requirements.

The intent of this CSAS process is to develop science advice to address these needs that is applicable at the national level to be used to provide additional measures to mitigate the impacts of seismic survey activities on cetaceans in general, and on at-risk species in particular. The information and recommendations from this meeting are intended to supplement, but not replace, the current SOCP. Note that this peer review was focused on the Maritimes Region as a case study. Publications resulting from the meeting will include a Science Advisory Report (DFO 2015), two Research Documents (Moors-Murphy and Theriault unpublished[1], Theriault and Moors-Murphy unpublished[2]), and these Proceedings.

[1] Moors-Murphy, H. and Theriault, J.A. (2015). Review of mitigation measures for cetacean Species at Risk during seismic survey operations. Fisheries and Oceans Canada. Unpublished manuscript.

[2] Theriault, J. and Moors-Murphy, H.B. (2015) Species at Risk criteria and seismic survey noise thresholds for cetaceans. Fisheries and Oceans Canada. Unpublished manuscript.

SOMMAIRE

Depuis l'entrée en vigueur de la *Loi sur les espèces en péril* (LEP) en 2002, l'exploitation pétrolière et gazière dans les eaux canadiennes fait l'objet d'un intérêt croissant de la part de l'industrie pétrolière extracôtière, et le nombre de permis d'exploration délivrés et de levés sismiques exécutés dans des parcelles au large de la Nouvelle-Écosse et de Terre-Neuve a augmenté. L'appel d'offres lancé en 2014 pour des parcelles au large de la Nouvelle-Écosse englobait des zones reconnues comme des habitats essentiels d'espèces de cétacés inscrites en tant qu'espèces en voie de disparition en vertu de la LEP. Les bruits sous-marins, en particulier les sons forts, peuvent avoir des effets néfastes sur les cétacés par l'intermédiaire d'un certain nombre de mécanismes et sont considérés comme une menace potentielle pour les individus et les populations. Des préoccupations ont donc été soulevées quant aux impacts potentiels de l'exploitation pétrolière et gazière et des activités de cartographie sur les cétacés inscrits en vertu de la LEP, particulièrement des bruits produits par les dispositifs de canons à air utilisés durant les levés sismiques.

Depuis 2008, l'Énoncé des pratiques canadiennes d'atténuation des ondes sismiques en milieu marin sert à orienter les exigences minimales en matière de mesures d'atténuation pour les opérations sismiques dans toutes les eaux marines libres de glace du Canada (MPO 2008). Toutefois, on a soulevé la question de savoir si les exigences générales de l'Énoncé des pratiques canadiennes étaient adéquates pour éviter les impacts interdits par la LEP sur les espèces de cétacés en péril et leur habitat essentiel. L'Énoncé lui-même précise que d'autres mesures d'atténuation ou des mesures modifiées pourraient être requises pour certaines espèces préoccupantes (MPO 2008); les membres de l'Association canadienne des producteurs pétroliers et leurs entrepreneurs en exploration sismique ont souvent mis en place des mesures d'atténuation supplémentaires déterminées au cours du processus d'évaluation environnementale afin de réduire davantage les impacts des activités de levés sismiques sur les espèces vulnérables et les zones marines sensibles. Toutefois, il existe actuellement peu de directives sur les mesures d'atténuation supplémentaires qui doivent être envisagées pour s'assurer d'éviter les impacts interdits par la LEP sur les cétacés inscrits en vertu de la LEP.

L'intérêt accru pour l'exploitation pétrolière et gazière et la cartographie dans les zones présentant un potentiel géophysique qui chevauchent les zones fréquentées par des cétacés inscrits en vertu de la LEP (y compris leur habitat essentiel désigné) a entraîné le besoin d'évaluer si l'Énoncé des pratiques canadiennes permettait d'éviter les impacts interdits par la LEP et de déterminer si des mesures d'atténuation modifiées ou supplémentaires étaient indiquées. En conséquence, le Secteur des sciences du MPO a été chargé de :

- déterminer les mesures et les seuils d'exposition au bruit pour les activités de levés sismiques, qui pourraient servir à éviter les impacts interdits par la LEP sur les cétacés inscrits en vertu de la LEP;
- fournir des conseils à savoir si l'application des mesures d'atténuation actuelles décrites dans l'Énoncé des pratiques canadiennes permettrait d'éviter les impacts interdits par la LEP sur les cétacés inscrits en vertu de la LEP;
- déterminer les modifications possibles à apporter à l'actuel Énoncé des pratiques canadiennes ou les mesures d'atténuation et de surveillance supplémentaires qui pourraient servir à répondre aux exigences de la LEP.

Ce processus du Secrétariat canadien de consultation scientifique vise à formuler un avis scientifique répondant à ces besoins et applicable à l'échelle nationale pour déterminer les mesures supplémentaires d'atténuation des impacts des activités de levés sismiques sur les cétacés en général et les espèces en péril en particulier. L'information et les recommandations qui ressortiront de la réunion compléteront, sans toutefois le remplacer, l'actuel Énoncé des pratiques canadiennes. Il est à noter que le présent examen par les pairs s'est concentré sur la région des Maritimes en tant qu'étude de cas. La réunion aboutira à la publication d'un avis scientifique (MPO 2015), de deux documents de

recherche (Moors-Murphy et Theriault, non publié[3], Theriault et Moors-Murphy, non publié[4]) ainsi que du présent compte rendu.

[3] Moors-Murphy, H. et J.A. Theriault (2015). *Review of mitigation measures for cetacean Species at Risk during seismic survey operations*, Pêches et Océans Canada, manuscrit non publié.

[4] Theriault, J. et H.B. Moors-Murphy (2015). *Species at Risk criteria and seismic survey noise thresholds for cetaceans*, Pêches et Océans Canada, manuscrit non publié.

DISCUSSION OF WORKING PAPER #1: SPECIES AT RISK CRITERIA AND SEISMIC SURVEY NOISE THRESHOLDS FOR CETACEANS (JAMES A. THERIAULT AND HILARY B. MOORS-MURPHY)

The objectives of this working paper were to answer the following question as set forth in the Terms of Reference:

1. Identify which sound exposure criteria (e.g., received sound level or exposure thresholds) could be used to avoid:
    1. physical harm/injury/mortality of individuals,
    2. harassment/disturbance of individuals; and
    3. destruction of critical habitat.

DFO (2004) developed a list of the potential effects (responses) of seismic airgun sounds on marine mammals, but did not directly relate these effects to SARA-prohibited impacts. SARA-prohibited impacts include "harm", "harassment", and "destruction" of critical habitat, which have been most recently defined as:

- Harm is "the adverse result of an activity where single or multiple events reduce the fitness (e.g., survival, reproduction, movement) of individuals" (DFO 2014).
- Harassment is "any act or series of acts which tend to disturb, alarm, or molest an individual or population, which by means of its frequency and magnitude results in changes to normal behavior(s) that reduce an individual's ability to carry out one or more of its life processes which could jeopardize the survival or recovery of the species" (most recent definition provided by DFO SARA Program, modified from the DFO (2009) definition of "harass" to incorporate results of recent supreme court decisions – see Provincial Court of British Columbia 2012).
- Destruction of critical habitat is "determined on a case by case basis. Destruction would result if part of the critical habitat were degraded, either permanently or temporarily such that it would not serve its function when needed by the species. Destruction may result from a single or multiple activities at one point in time or from the cumulative effects of one or more activities over time" (EC 2009).

The Committee reviewed the list of potential effects/responses presented in Table 1 (below, (from DFO 2015; Theriault and Moors-Murphy unpublished[2]), which includes the effects listed in DFO (2004) with some modifications, and populated the remainder of the table to outline the potential direct and indirect impacts/consequences of these effects/responses on marine mammal physiology, behavior and ecology, and to link these effects/responses to the SARA-prohibited impacts to which they apply.

The Committee then reviewed the list of potential effects/responses presented in Table 2 (below, from DFO 2015) and populated the remainder of the table to summarize any existing evidence to support the occurrence of these effects/responses in cetaceans in the context of determining appropriate sound exposure metrics for establishing thresholds for seismic airgun sounds to avoid SARA-prohibited impacts. Existing knowledge gaps to be addressed were also identified by the committee and captured in Table 2. Due to the substantial knowledge gaps identified, the Committee was not able to evaluate whether acoustic thresholds reported in the literature are relevant or acceptable for avoiding SARA-prohibited impacts. The Committee did, however, discuss research required to help address these knowledge gaps which are included

in the Science Advisory Report (DFO 2015). Note that there were no major points of contention while undertaking this exercise.

2. During the discussion about Table 1, it was noted that:

- The original list off potential effects presented in Table 1 was a combination of what could be considered biological effects/responses and impacts/consequences. It was suggested that the focus should be on impacts/consequences, although it was recognized that some biological effects/responses might not have observable impacts/consequences. It was thus determined that the table should include both, effects/responses and corresponding impacts/consequences. Table 1 was modified accordingly.
- "Chronic effects" should actually be considered as impacts/consequences rather than effects/responses. Almost all of the listed effects/responses could have acute or chronic impacts/consequences, so "chronic effects" shouldn't be listed in isolation. Table 1 was modified accordingly.
- Chronic (cumulative) exposures will have different impacts than a single exposure event.
- Physiological effects may not be observable; for example, certain types of hearing loss may not visibly impact behavior.
- Many significant behavioral impacts are not observable in marine mammals or may be very difficult to measure and quantify.
- Impacts on the most vulnerable individuals may not be observable. For example, unhealthy or animals in poor condition may not react in the same way as healthy or animals in good condition (e.g., animals in poor condition may stay within an area in circumstances under which they would normally leave due to the energetic expense). Similarly, resident animals may not react in the same way as migratory/transient animals (e.g., resident animals may stay within an area in circumstances under which they would normally leave because they have nowhere else to go).

During the discussions about thresholds for the SARA-prohibited impact "kill" it was noted that:

- "Stranding" should be expanded to include at-sea deaths. Stranding/at-sea death is an impact/consequence rather than an effect/response. For example, stranding/at-sea death could be a direct consequence of changes in dive or respiratory patterns or an indirect consequence of non-auditory physiological effects. Table 1 was modified accordingly.
- There is currently no definitive evidence that marine mammal strandings are caused by seismic airgun sounds, so the Committee was not able to quantify relevant thresholds for avoiding stranding/at-sea deaths.
- It was noted that strandings or at-sea deaths caused by offshore anthropogenic activities are difficult to quantify without appropriate at-sea monitoring as there is often a lag in space and time between the event and when the carcass reaches the shore, and in many cases the carcass may never reach shore. Development of a protocol to monitor for stranding events or at-sea deaths during seismic survey activities was recommended to help address this area of uncertainty.

During the discussions about thresholds for the SARA-prohibited impact "harm" it was noted that:

- There are acoustic thresholds that have been established for auditory physiological effects elsewhere in the world. NOAA (2013) proposed a combination of peak pressure and cumulative Sound Exposure Level thresholds for temporary (TTS) and permanent hearing

threshold shifts (PTS) in marine mammals. These thresholds were developed building on Southall et al. (2007), using the most up-to-date information on TTS and PTS in marine mammals; however, they are only proposed thresholds and are currently undergoing review. The adequacy of the NOAA (2013) thresholds for avoiding SARA-prohibited impacts on cetaceans in Canadian waters should be assessed by conducting an independent analysis/review of the NOAA thresholds in the Canadian context. The Committee did not have the expertise or relevant data to conduct such a review during this meeting, and so could not make recommendations regarding the adequacy of the NOAA approach for establishing thresholds for SARA-listed cetaceans.

- In the Canadian Beaufort, the safety zones are calculated based on NOAA (2000) thresholds and modified according to local conditions, as the size of the threshold-based safety zone varies with depth and bottom topography due to the influence of these features have on sound propagation (e.g. the safety zone calculations based on the NOAA (2000) 180 dB threshold can vary from 500 m in deep water to 2000 m in shallow water in this region). The 500 m safety zone specified in the SOCP may therefore be sufficient for avoiding physical injury in deep water in the Canadian Arctic, but not in shallow water. The NOAA (2000) thresholds have thus been informally adopted for use in the Canadian Beaufort Sea for establishing the safety zone radius, as this is a more precautious approach.
- It was unclear if TTS should be considered as "harm" as defined by SARA.
- Therefore, there are data available that could be used to help develop quantitative thresholds for avoiding potential physiological effects (e.g., TTS and PTS), but further work is required to determine thresholds to avoid SARA-prohibited physiological impacts. This is included as a research recommendation in the Science Advisory Report (DFO 2015).
- Stress should be included as an impact/consequence of non-auditory physiological effects. Tables 1 and 2 were updated accordingly.
- Chronic impacts/consequences could be considered "harm", but it is difficult to determine if these chronic impacts/consequences are significant in terms of the SARA-prohibited impacts.
- Whether or not changes in dive and respiratory patterns could be considered a SARA-prohibited impact depends on the impacts/consequences of the change observed and specific threats. There are cases where changes in dive and respiratory patterns could result in "harm" or "harassment", but species-specific research is needed to determine at what levels such changes become significant in terms of SARA-prohibited impacts.

During the discussions about thresholds for the SARA-prohibited impact "harass" it was noted that:

- There is currently no existing definitive evidence that seismic airgun sounds impact or change the social behavior of marine mammals.
- There is evidence that seismic airgun sounds impact or change the vocal behavior of some marine mammal species, and both increased and decreased vocalization rates in the presence of seismic airgun sounds have been reported. Acoustic thresholds for avoiding such changes are likely to be species-, context- and project-specific, and thus are difficult to determine.

After much discussion, the Committee concluded that with the data and information available to the meeting participants, it was not possible to identify sound exposure criteria (e.g., received

sound level or exposure thresholds) that could be used to avoid "harm", "harassment" or "destruction" of critical habitat.

DISCUSSION OF WORKING PAPER #2: REVIEW OF MITIGATION MEASURES FOR CETACEAN SPECIES AT RISK DURING SEISMIC SURVEY OPERATIONS (HILARY B. MOORS-MURPHY, JAMES A. THERIAULT)

The objectives of this working paper were to answer the following questions as set forth in the Terms of Reference:

1. Identify whether the application of the current requirements outlined in the SOCP avoid (a), (b) and (c) as listed in the objectives for Working Paper #1 above.
2. If not, based on scientific literature and new studies completed since the development of the SOCP, identify modifications to the current SOCP or additional mitigation and monitoring measures that could be used to avoid or minimize the occurrence of (a), (b) and (c).

Even though sound exposure criteria for establishing acoustic thresholds could not be established during this meeting, it was determined that the adequacy of the SOCP for avoiding SARA-prohibited impacts could be assessed on a precautionary basis. The Committee therefore evaluated the mitigation measures outlined in the SOCP on a precautionary basis to determine whether they are appropriate for avoiding SARA-prohibited impacts, using the three case-study species (Scotian Shelf northern bottlenose whales, North Atlantic right whales and Altantic blue whales) as examples. The Committee discussed and populated Table 3 (below, taken from Moors-Murphy and Theriault unpublished[1]) for each of the three case-study species. Because the same conclusions were drawn for each case-study species, it was discussed that the resulting recommendations would likely apply to all SARA-species and therefore Table 3 provides recommendations for any SARA-listed cetacean in general. Note that there were no major points of contention while undertaking this exercise.

During the discussion about Table 3, it was noted that:

- Most of the mitigation measures of the SOCP are likely to reduce potential SARA-prohibited impacts on SARA-listed cetaceans to some degree, but their effectiveness can vary greatly depending on if or exactly how the measures are implemented.
- The SOCP as a whole is more effective than any one measure on it's own.
- The only mitigation measures of the SOCP that address potential SARA-prohibited impacts (such as "harm", "harassment" or "destruction" of critical habitat) that may occur beyond the safety zone are measures 4 and 5. When planning seismic survey activities, operators should consider mitigation for these potential effects that may occur outside the safety zone.
- Based on the NOAA 2013 study, results presented (which examined visual detection rates for various baleen and toothed whale species of the North Pacific), the Committee concluded that a the probability of detecting animals within the safety zone using traditional visual detection methods is generally low and not likely sufficient, especially during higher sea states and in poor visibility conditions. Additional monitoring techniques/methods may be required to increase the probability of detection to more acceptable levels, such as use of additional observation platform(s) to monitor for marine mammals, combined visual and passive acoustic monitoring (PAM) of the safety zone, adequate marine mammal observer (MMO) training, increasing the 30-minute pre-ramp up

observation period, etc. It was therefore recommended that a combination of monitoring methods should be used to ensure SARA-listed cetaceans that may occur within the safety zone can be reliably detected.

- Effective mitigation during seismic surveys require a relatively high probability of detection of animals for avoiding potential SARA-prohibited impacts that may occur in close proximity to the airgun array on SARA-listed species. There are ways to estimate this probability of detection for a species based on the detection methods used. An acceptable target probability of detection within the safety zone for each SARA-listed cetacean species should be determined, which can then be used to determine the appropriate and required detection methods needed to meet the target probability of detection. This analysis has not yet been done, but is possible.
- There is some standardization of MMO training worldwide (industry-driven), but this is not regulated in any way in Canada. A standardized method of determining if an MMO is "qualified" is needed in Canada.
- It was noted that the number of MMOs on duty at any one time may have as important of an effect on the probability of detection as the qualifications of the MMOs.
- There is some evidence that disagreements between MMOs and operators (regarding sightings of marine mammals) may impact mitigation measures (e.g., delayed ramp-up, shut-downs, etc).

Table 1. List of potential effects/responses (modified from DFO 2004) and potential impacts/consequences of seismic airgun sounds on marine mammal physiology, behavior and ecology, and SARA prohibited impact category to which they apply based on the most recent definitions. Examples of studies providing evidence of seismic airgun sounds causing a particular effect/response are provided. Under SARA prohibited impact categories, black circles indicate a direct link between the potential effect and SARA prohibited impact while grey circles indicate an indirect link between the potential effect and SARA prohibited impact.

Potential effects/responses	Direct potential impacts/consequences	Indirect potential impacts/consequences	Kill	Harm[5]	Harass[6]	Destroy[7]
		Physiology				
Non-auditory physiological effects	Emboli formation, organ/ tissue damage, neurological effects, increased stress hormones	Stranding/near-stranding/at-sea death, reduced socializing/foraging, malnutrition, reduced reproduction/survival	○	●	○	
Auditory physiological effects (e.g. TTS, PTS) (Finneran et al. 2002)	Loss of hearing	Reduced socializing/foraging, malnutrition, starvation, increased exposure to threats, reduced reproduction/survival	○	●	○	
		Behavior				
Changes in dive and respiratory patterns (Jochens et al. 2006; Gailey et al. 2007)	Stranding/near-stranding, emboli formation, tissue damage, increased energetic cost, reduced socializing/foraging	Stranding/near-stranding/at-sea death, malnutrition, increased exposure to threats, reduced reproduction/survival	○	●	●	

[5] Based on following definition of harm: "the adverse result of an activity where single or multiple events reduce the fitness (e.g., survival, reproduction, movement) of individuals" (DFO 2014).

[6] Based on following definition of harass: "any act or series of acts which tend to disturb, alarm, or molest an individual or population, which by means of its frequency and magnitude could reduce the likelihood of recovery or survival of the species by changing its normal behavior(s) and thus impacting a life history function" (unpublished report).

[7] Based on following definition of destruction of critical habitat: "if part of the critical habitat were degraded, either permanently or temporarily such that it would not serve its function when needed by the species" (EC 2009).

Potential effects/responses	Direct potential impacts/consequences	Indirect potential impacts/consequences	Kill	Harm[5]	Harass[6]	Destroy[7]
Displacement and migratory diversion (Richardson et al. 1986; Miller et al. 1999; Bain and Williams 2006; Moore and Angliss 2006)	Increased energetic cost, reduced socializing/foraging	Malnutrition, increased exposure to threats, reduced reproduction/survival		●	●	●
Changes in social behavior (e.g. hampered parental care and bonding, hampered breeding, etc.)	Reduced socializing/foraging	Calf mortality, reduced reproduction/ survival			●	●
Changes in vocalization patterns (*e.g.* hampered communication and echolocation) (Clark and Gagnon 2006; Di Lorio and Clark 2006; Castellote et al. 2012)	Reduced socializing/foraging	Malnutrition, reduced reproduction/survival			●	●
Changes in time budget (*e.g.* proportion of time spent performing various activities such as resting, foraging, socializing)	Increased energetic cost, reduced socializing/ foraging/resting	Malnutrition, increased exposure to threats, reduced reproduction/ survival		●	●	●
Changes in cognitive processes (*e.g.* distraction)	Reduced socializing/foraging	Malnutrition, increased exposure to threats, reduced reproduction/ survival			●	
Ecology						
Hampered passive acoustic detection of prey, predators, and conspecifics	Predator-related injury/mortality, reduced socializing/foraging	Malnutrition, increased exposure to threats, reduced reproduction/ survival	●	●	●	●
Hampered avoidance of anthropogenic threats (e.g., ship strikes, bycatch, etc)	Anthropogenic injury/mortality	Increased exposure to threats, reduced reproduction/ survival	●	●	●	
Hampered use of critical habitat/reduced occupancy	Reduced socializing/foraging	Reduced reproduction/ survival				●

Table 2. Summary of information available and knowledge gaps to be addressed in relevance to determining the appropriate sound exposure metrics that could be used to establish thresholds for each potential effect/response of seismic airgun sounds on cetaceans.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
		Physiological effects	
Non-auditory physiological effects	None determined	May be related to changes in dive and respiratory patterns. Currently no evidence of emboli formation or hemorrhaging linked to seismic airgun sounds (DFO 2010). Increased stress hormone levels in cetaceans have been linked to increased vessel traffic and underwater noise levels (Rolland et al. 2012).	Probability of detecting physical injuries or at-sea deaths caused by seismic airgun sounds during offshore activities is low due to distance from shore, sinking carcasses and limited ability to respond to such incidents and perform necropsies in a timely manner. Currently no measurements of stress hormone levels in cetaceans during seismic surveys. Long-term impacts of increased stress hormone levels unknown but likely to include decreased immunity and fertility, as the stress response is highly conserved across species (Wright et al. 2007a,b).
Auditory physiological effects (*e.g.* TTS, PTS)	Metrics related to TTS, PTS (e.g., Sound Pressure Level,Sound Exposure Level (SEL), Cummulative SEL, Peak Amplitude)	Some information on TTS available, less information available on PTS (e.g., Southall et al. 2007). A variety of metrics have been used for establishing quantitative TTS/PTS thresholds (NOAA 2000, Southall et al. 2007, NOAA 2013).	PTS generally not empirically measured but derived from TTS. Thresholds for TTS/PTS based on a small set of measurements from a limited number of species.
		Behavioral effects	
Changes in dive and respiratory patterns	None determined	Some studies show changes in dive behavior (e.g., fluke rate) and respiratory rate during seismic surveys (Abgrall et al. 2008).	Uncertainty in the most appropriate responses to measure (e.g., fluke rate, ascent/descent rate, dive duration, dive depth?) or how such responses relate to various sound exposure metrics. Responses variable and highly species/context specific, thresholds likely to be species dependent. Species-specific case studies examining frequency and magnitude of response needed. Long-term impacts of increased energetic costs unknown but can be estimated/calculated.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
Displacement and migratory diversion	None determined	Some mysticete species known to move away from seismic activities (Miller et al. 1999, Moore and Angliss 2006), which likely have an energetic cost (Claridge 2013). However, in both, mysticete and odontocete species, the response is varied (Jochens et al. 2006; Miller et al. 2006; Smultea et al. 2004; Moulton and Miller 2005; Bain and Williams 2006; Harris et al. 2007; Holst et al. 2006; Stone and Tasker 2006; Weir 2008).	Uncertainty in the most appropriate responses to measure (e.g., changes in swim direction, speed?) or how such responses relate to various sound exposure metrics. Responses variable and highly species/context specific, thresholds likely to be species dependent. Species-specific case studies examining frequency and magnitude of response (i.e. effect on vital rates and population-level impacts) needed. Long-term impacts of increased energetic costs unknown but can be estimated/calculated.
Changes in social behavior (*e.g.* hampered parental care and bonding, hampered breeding, etc.)	None determined	May be related to displacement, changes in vocalization patterns, hampered passive acoustic detection of conspecifics. It has been noted that mothers with calves are more sensitive to (respond to lower levels of) to seismic airgun sounds (McCauley et al. 2000).	Relationship between displacement and hampered parental care unknown. Uncertainty in the most appropriate responses to measure or how such responses relate to various sound exposure metrics. Responses likely variable and highly species/context specific, thresholds are likely to be species dependent. Species-specific case studies examining frequency and magnitude of response needed. Long-term impacts of generally unknown.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
Changes in vocalization patterns (*e.g.* hampered communication and echolocation)	Metrics related to changes/reduction in communication space	May be related to hampered passive acoustic detection of conspecifics and prey. Changes in vocalization patterns (e.g., increased/decreased vocalization rates, changes in call frequency, source levels) linked to seismic airgun sounds have been documented in some species (Clark and Gagnon 2006; Di Iorio and Clark 2010; Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999a, 1999b; Nieukirk et al. 2004, 2012; Smultea et al. 2004; Holst et al. 2005a, 2005b, 2006, 2011; Dunn and Hernandez 2009; Cerchio et al. 2010). Evidence of reduced communication space and masking as a result of seismic sound production exists, particularly important for low-frequency vocalizers (Clark and Gagnon 2006, Di Iorio and Clark 2006). This was noted as an important area to investigate due to wide-ranging impacts.	Uncertainty in how such responses relate to various sound exposure metrics. Responses variable and highly species/context specific, thresholds likely to be species dependent. Species-specific case studies examining frequency and magnitude of response are needed. Long-term impacts of changes in vocalization patterns and communication space generally unknown.
Changes in time budget (*e.g.* proportion of time spent performing various activities such as resting, foraging, socializing)	None determined		Not known if this occurs.
Changes in cognitive processes (*e.g.* distraction)	None determined	Changes in cognitive processes due to anthropogenic noise have been shown to occur in some fauna. They result in hampering efficient foraging (Purser and Radford 2011), increased predation risk (Chan et al. 2010), but have been considered in general decision making for marine mammals (Bateson 2011)	Not known if this occurs in marine mammals.

Potential effects/responses	Potential sound exposure metric(s)	Information available	Knowledge gaps
		Ecosystem effects	
Hampered passive acoustic detection of prey, predators, and conspecifics	Metrics related to changes/reduction in communication space	May be related to auditory physiological effects. Because predators/prey make sound, some evidence that passive acoustic detection of predators/prey may be important for some species – e.g., beaked whale species have been observed responding to killer whale playbacks by leaving the vicinity (Tyack et al 2011).	Not known if baleen whales passively acoustically detect prey. Uncertainty in how such responses relate to various sound exposure metrics. Long-term impacts of changes in communication space generally unknown.
Hampered avoidance of anthropogenic threats (e.g., ship strikes, bycatch, etc)	Metrics related to changes/reduction in communication space	May be related to auditory physiological effects and hampered passive acoustic detection. Some evidence that hearing impaired species increases vulnerability to ship strikes and entanglement (DFO 2004, Abgrall et al. 2008).	Links between exposure to seismic airgun sounds and increased exposure to threats uncertain.
Hampered use of critical habitat/reduced occupancy	None determined	May be related to hampered passive acoustic detection.	Not known if this occurs.

Table 3. Review of mitigation and monitoring measures of the SOCP and their likely effectiveness/ability to avoid SARA-prohibited impacts when properly implemented ("avoid" = measure likely to help avoid prohibited impacts, "reduce" = measure likely to reduce likelihood but not altogether avoid prohibited impacts, "unknown" = effectiveness not known), and recommended modifications or additional mitigation measures to be considered.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Planning		
3. Each seismic survey must be planned to: (a) use the minimum amount of energy necessary to achieve operational objectives; (b) minimize the proportion of the energy that propagates horizontally; and, (c) minimize the amount of energy at frequencies above those necessary for the purpose of the survey.	reduce/avoid	Seismic surveys should also be planned to minimize the area surveyed and duration of the survey to the extent possible, with particular consideration given to avoiding identified critical habitat of threatened and endangered cetacean species when such species are expected to be present in the area.
4. All seismic surveys must be planned to avoid: (a) a significant adverse effect for an individual marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; and, (b) a significant adverse population-level effect for any other marine species.	avoid	Seismic surveys should also be planned to avoid harm and harassment of individuals and destruction of critical habitat of threatened and endangered marine mammals.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
5. Each seismic survey must be planned to avoid: (a) displacing an individual marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act* from breeding, feeding or nursing; (b) diverting an individual migrating marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act* from a known migration route or corridor; (c) dispersing aggregations of spawning fish from a known spawning area; (d) displacing a group of breeding, feeding or nursing marine mammals, if it is known there are no alternate areas available to those marine mammals for those activities, or that if by using those alternate areas, those marine mammals would incur significant adverse effects; and, (e) diverting aggregations of fish or groups of marine mammals from known migration routes or corridors if it is known there are no alternate migration routes or corridors, or that if by using those alternate migration routes or corridors, the group of marine mammals or aggregations of fish would incur significant adverse effects.	avoid	If a seismic survey area overlaps the distributional range of a SARA-listed species but finer-scale distribution patterns within the area of interest are not well known, then timely pre-survey studies at the appropriate temporal and spatial scales should be conducted prior to the survey to assess species occurrence and increase understanding of the likelihood of displacing or diverting individuals.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Safety zone and start-up		
6. Each seismic survey must: (a) establish a safety zone which is a circle with a radius of at least 500 meters as measured from the center of the air source array(s); and for all times the safety zone is visible, a qualified Marine Mammal Observer must continuously observe the safety zone for a minimum period of 30 minutes prior to the start up of the air source array(s); and, (b) maintain a regular watch of the safety zone at all other times if the proposed seismic survey is of a power that it would meet a threshold requirement for an assessment under the *Canadian Environmental Assessment Act*, regardless of whether the Act applies.	Reduce	(a) The safety zone radius should be the most conservative of 500 meters or a radius determined using propagation models based on the best available data and science for a pre-determined acoustic threshold (which has yet to be established), taking into account to the extent possible the species, environment and sound source context, and which should be validated with field measurements. (b) Combined monitoring capabilities should be designed to maximize the probability of detecting SARA-listed species to achieve a target probability of detection within the safety zone consistent with SARA requirements (which has yet to be established). A combination of detection methods/technologies (not limited to MMOs and PAM) may be required to achieve the target probability of detection. When operating in areas overlapping the distribution of deep-diving SARA-listed cetaceans, the pre start-up (or restart-up) observation period should be extended to a minimum of 60 minutes to increase the probability of detecting deep-diving species, and ideally should be determined based on the maximum duration of at least one deep-dive cycle.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
7. If the full extent of the safety zone is visible, before starting or restarting an air source array(s) after they have been shut-down for more than 30 minutes, the following conditions and processes apply: (a) none of the following have been observed by the Marine Mammal Observer within the safety zone for at least 30 minutes: (i) a cetacean or sea turtle; (ii) a marine mammal listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; or, (iii) based on the considerations set out in sub-section 4(b), any other marine mammal that has been identified in an environmental assessment process as a species for which there could be significant adverse effects; and, (b) a gradual ramp-up of the air source array(s) over a minimum of a 20 minute period beginning with the activation of a single source element of the air source array(s), preferably the smallest source element in terms of energy output and a gradual activation of additional source elements of the air source array(s) until the operating level is obtained.	(a) reduce (b) unknown	(a) See 6(b) above. (b) Effectiveness is likely to be dependent on the nature and level of the animals' responsiveness, which may vary by species and context. A review of available literature and additional studies is required to fully understand effectiveness.
Shut-down of air source array		
8. The air source array(s) must be shut down immediately if any of the following is observed by the Marine Mammal Observer in the safety zone: (a) a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; or, (b) based on the considerations set out in sub-section 4(b), any other marine mammal or sea turtle that has been identified in an environmental assessment process as a species for which there could be significant adverse effects.	reduce	The immediate shutdown of the airgun array should apply when detection occurs within the safety zone by any monitoring method or technique used, and should also occur before the animal enters the safety zone if it is anticipated, by any monitoring technique, that the animal will enter the safety zone based on its movement pattern.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Line changes and maintenance shut-downs		
9. When seismic surveying (data collection) ceases during line changes, for maintenance or for other operational reasons, the air source array(s) must be: (a) shut down completely; or, (b) reduced to a single source element.	(a) reduce (b) unknown	(a) During line changes or operational maintenance the airgun array should only be shut-down completely if the safety zone can be effectively monitored (i.e., the target probability of detection can be obtained) before ramping back up; otherwise, the air source array should be reduced to a single source element or operations should be delayed until the safety zone can be effectively monitored. (b) During line changes or operational maintenance the airgun array should only be reduced to a single source element if the safety zone cannot be effectively monitored before ramping back up. Effectiveness is likely to be dependent on the nature and level of the animals' responsiveness, which may vary by species and context. A review of available literature and additional studies is required to fully understand effectiveness.
10. If the air source array(s) is reduced to a single source element as per subsection 9(b), then: (a) visual monitoring of the safety zone as set out in section 6 and shut-down requirements as set out in section 8 must be maintained; but, (b) ramp-up procedures as set out in section 7 will not be required when seismic surveying resumes.	(a) reduce (b) unknown	(b) Ramp-up should be conducted as appropriate even when the airgun array is reduced to a single source element.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Operations in low visibility		
11. Under the conditions set out in this section, cetacean detection technology, such as Passive Acoustic Monitoring, must be used prior to ramp-up for the same time period as for visual monitoring set out in section 6. Those conditions are as follows: (a) the full extent of the safety zone is not visible; and, (b) the seismic survey is in an area that: (i) has been identified as critical habitat for a vocalizing cetacean listed as endangered or threatened on Schedule 1 of the Species at Risk Act; or, (ii) in keeping with the considerations set out in sub-section 4(b), has been identified through an environmental assessment process as an area where a vocalizing cetacean is expected to be encountered if that vocalizing cetacean has been identified through the environmental assessment process as a species for which there could be significant adverse effects.	reduce	See 6(b) above.
12. If Passive Acoustic Monitoring or similar cetacean detection technology is used in accordance with the provision of section 11, unless the species can be identified by vocal signature or other recognition criteria: (a) all non-identified cetacean vocalizations must be assumed to be those of whales named in sections 8(a) or (b); and, (b) unless it can be determined that the cetacean(s) is outside the safety zone, the ramp-up must not commence until non-identified cetacean vocalizations have not been detected for a period of at least 30 minutes.	reduce	(b) See caveat about deep-diving species on 6(b) above.

Mitigation measure (from the SOCP)	Effectiveness	Recommendations for modifications/additions
Additional mitigation measures and modifications		
13. Persons wishing to conduct seismic surveys in Canadian marine waters may be required to put in place additional or modified environmental mitigation measures, including modifications to the area of the safety zone and/or other measures as identified in the environmental assessment of the project to address: (a) the potential for chronic or cumulative adverse environmental effects of: (i) multiple air source arrays (e.g., two vessels on one project; multiple projects); or, (ii) seismic surveys being carried out in combination with other activities adverse to marine environmental quality in the area affected by the proposed program or programs; (b) variations in sound propagation levels within the water column, including factors such as seabed, geomorphologic, and oceanographic characteristics that affect sound propagation; (c) sound levels from air source array(s) that are significantly lower or higher than average; and, (d) species identified in an environmental assessment process for which there is concern, including those described in sub-section 4b).	reduce	
14. Variations to some or all of the measures set out in this Statement may be allowed provided the alternate mitigation or precautionary measures will achieve an equivalent or greater level of environmental protection to address the matters outlined in sections 6 through 13 inclusive. Where alternative methods or technologies are proposed, they should be evaluated as part of the environmental assessment of the project.	reduce	
15. Where a single source element is used and the ramping up from an individual air source element to multiple elements is not applicable, the sound should still be introduced gradually whenever technically feasible.	reduce	

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APPENDIX 1: TERMS OF REFERENCE

REVIEW OF MITIGATION AND MONITORING MEASURES FOR SEISMIC SURVEY ACTIVITIES IN AND NEAR THE HABITAT OF CETACEAN SPECIES AT RISK

National Peer Review – National Capital Region

March 25-27, 2014
Halifax, Nova Scotia

Chairperson: Don Bowen

Context

There has been increasing interest in oil and gas development in Canadian waters by the Offshore Petroleum Industry. Exploration licenses have recently been issued for land parcels off Nova Scotia and Newfoundland, and the most recent call for bids off Nova Scotia included areas immediately adjacent to identified critical habitat of cetacean species listed as endangered under the Species at Risk Act(SARA). A call for bids for additional areas that may overlap with or abut identified critical habitat is anticipated in 2014. Concerns have been raised about the potential impacts of oil and gas activities on SARA-listed cetacean species, particularly noise produced by seismic airgun arrays during seismic surveys.

Since 2007, the Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment (SOCP) has been used to guide minimum standard mitigation requirements for seismic operations in Canada. The SOCP was developed to mitigate potential negative population-level impacts of seismic sound produced during seismic surveys on marine mammals. Under the SARA, however, protection from harm, harassment and mortality is provided at the individual-level, and specific areas of identified critical habitat are to be protected from destruction.

The generic requirements of the SOCP may not be adequate to avoid impacts to Species at Risk and their critical habitat. The SOCP itself states that additional or modified mitigation measures may be required for species of concern. The increased interest in oil and gas development in areas frequented by SARA-listed cetaceans, including areas in/near identified critical habitat, has led to a need to evaluate the ability of the SOCP to prevent impacts to SARA-listed species, and to determine if additional or modified mitigation and monitoring measures are needed to avoid harm and harassment of individuals or destruction of their critical habitat. The intent of this process is to develop science advice that is applicable at the national level in order to be used to provide additional measures to monitor and mitigate the impacts of seismic survey activities on cetaceans in general and Species at Risk in particular. This information is intended to supplement, but not replace, the current SOCP.

Objectives

With respect to the potential impact of seismic surveys (both small airgun arrays and wide azimuth surveys) on cetaceans, and in particular on SARA-listed species including Scotian Shelf Northern Bottlenose Whales, North Atlantic Right Whales, and Atlantic Blue Whales (all Endangered):

- Identify which sound exposure criteria (e.g., received sound level or exposure thresholds) could be used to avoid:
    - (a) physical harm/injury/mortality of individuals,
    - (b) harassment/disturbance of individuals; and
    - (c) destruction of critical habitat

- Identify whether the application of the current requirements outlined in the SOCP avoid (a), (b) and (c) above, and;
- If not, based on scientific literature and new studies completed since the development of the SOCP, identify modifications to the current SOCP or additional mitigation and monitoring measures that could be used to avoid or minimize the occurrence of (a), (b) and (c).

Note that studies for this peer review will be focused on the Maritimes Region as a case study.

Participation

- DFO Science
- DFO Ecosystem Management (Species at Risk Management Division, Oceans and Coastal Management Division)
- DFO Policy and Economics
- Academic experts
- Consulting experts
- Offshore Petroleum Boards
- The Canadian Association of Petroleum Producers
- Environmental NGOs
- Natural Resources Canada

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